A thermally insulated container and use thereof

The invention relates to a thermally insulated container for the transport of cargo, said container comprising panels comprising at least one outer layer or one wall and at least one inner layer or one wall, between which layers or walls foam material is arranged, the layers or walls being of metal and having a thickness in excess of 50 μm.

In connection with the transport of cargo where the temperature thereof is desired to assume a specified value, thermally insulated containers are used. This is the case eg during the transport of meat for human consumption and the like. In connection with such transport it is essence that the temperature is maintained, and therefore it is essential that the thermal conductivity of the container is minimal. It is known to use containers constructed from panels, whose walls can be made of eg metal, and between which a foam material is blown. Likewise, it is known to use containers with walls manufactured from a suitable plastics material, and between which a foam material is blown. In connection with the manufacture of these panels, polyurethane foam is typically used as foam material, and blowing agents are the ones available on the market. It is thus desirable to provide containers, where the thermal conductivity is minimal, while simultaneously environmentally acceptable blowing agent can be used.

It is also known that in case the selected insulation material comprises polyurethane foam with a closed cell structure, it contains a mixture of blowing-agent gas and at least one additive gas. The additive gas may comprise inert gases – eg argon – the coefficient of diffusion of which is lower than that of atmospheric air. Furthermore the foam may be rigid or semi-rigid.

It is thus the object of the present invention to provide a thermally insulated container, whose insulating properties are good and wherein the good thermal insulating properties are maintained, also over a number of years, the insulating properties of the panels remaining substantially unchanged over time.

This object is obtained with a thermally insulated container of the kind described above, and wherein the foam material is essentially a closed-cell foam material, said cells enclosing at least to gases, said gases having a thermal conductivity λ that is lower than that of atmospheric air, and wherein the gases comprise at least one blowing-agent gas and at least one additive gas and is present in the cells in a amount by weight corresponding to a closed interval corresponding to the ratio of 50:1 to 400:1.

The panels of the containers are thus manufactured in accordance with essentially known principles, but wherein other gases are used in connection with the provision of the polyurethane foam, such that the ready-hardened polyurethane foam on the one hand comprises a small cell structure constituted by closed cells, and wherein these closed cells incorporate the blowing agent used in the manufacture of the polyurethane foam and the additive gas used, viz. materials whose thermal conductivity properties are markedly inferior to that of atmospheric air. The ratio between the two gases – blowing agent and additive gas – will be within the closed interval of 50:1 to 400:1 percent by weight.

As a consequence of the foam material comprising, on the one hand, the closed cells, it is hence ensured that they are filled with these gases that have a low thermal conductivity. Since the walls are made of metal it is also ensured that no diffusion of the gas occurs as it has happened eg over a number of years when walls were built of plastics material, and likewise the small amounts of additive gas – preferably argon – optimise the insulating

properties. Said percentage by weight corresponds to a percentage in volume of additive gas of 0.48-2.85 percent by volume and an optimal content being within the range of 0.6 percent by volume.

By providing a thermally insulated container according to the invention and as further featured in claim 2, convenient choice of foam is obtained and which is particularly suitable for precisely use for a container.

By providing a thermally insulated container according to the invention and as further featured in claim 3, a value for the thermal conductivity is accomplished that ensures a markedly superior insulation compared to those cases where the gas is enclosed in the cells and is constituted of atmospheric air.

By providing a thermally insulated container according to the invention as further featured in claim 4, a convenient choice of gas is accomplished.

By providing a thermally insulated container according to the invention as further featured in claim 5, a convenient choice of material is accomplished, which material is, on the one hand, diffusion proof and ensures good strength, since an aluminium alloy will primarily be used for coating the walls that face towards the container interior, and wherein a convenient steel alloy is used for coating the walls that face towards the surroundings.

By providing a thermally insulated container according to the invention and as further featured in claim 6, a convenient thickness of the insulating layer is accomplished, and also that it fills the entire space within the panel thereby eliminating the occurrence of heat bridges.

By providing a thermally insulated container according to the invention as further featured in claim 7, a rigid construction is accomplished, since said

foam materials have carrying capacities that ensure that the panels have a good and convenient strength, while simultaneously it is ensured that the cell structure becomes the desired closed-cell structure.

By providing a thermally insulated container according to the invention as further featured in claim 8, a cell size is accomplished that ensures that the insulating properties are maintained, and that thus an optimal relation is accomplished between cell size and the selected gas.

By providing a thermally insulated container according to the invention and as further featured in claim 9 it is accomplished that the gas is retained in the cells and that consequently their insulating capacity is maintained. This is of significance when the walls are manufactured from a plastics material, whereas it is of no consequence when the surrounding walls are manufactured from metal.

By providing a thermally insulated container according to the invention and as recited in claims 10 and 11, a convenient choice of gas is accomplished.

The invention also relates to use of the thermally insulated container for being integrated/incorporated in a vehicle for providing a container vehicle/refrigerated vehicle. Hereby a refrigerated vehicle having good thermally insulating properties is obtained.

The invention will now be explained in further detail with reference to the drawing, wherein:

Figure 1 shows a plant for admixture of additive gas with the blowing-agent gas;

Figure 2 shows a thermally insulated container;

Figure 3 shows a sectional view of a panel for the construction of a thermally insulated container;

Figure 4 shows a sectional view of polyurethane foam with cells;

Figure 5 shows the thermal conductivity for selected material as a function of the temperature measured in a wall.

In connection with the manufacture of polyurethane foam for use in the manufacture of panels for containers a plant like the one shown in Figure 1 is used. In the context of this plant, argon is used for being blown into the emulsifier 4.

Argon is admixed with polyol in the emulsifier 4 which is, in reality, a radial-flow mixer taken from the low-pressure machine programme. The emulsifier 4 is to be mounted on a return conduit for a polyol tank 1 with influx of polyol at the side and discharge from a central opening in the bottom element of the tank 1. A stirrer 2 is located within the tank 1 as such. The argon used must be dry and free from oil, is conveyed to the emulsifier through a needle valve 8, a flow meter 7, a magnetic valve 6 and a non-return valve 5 in that sequence. The magnetic and non-return valves need to be mounted directly on the emulsifier.

Argon serves the purpose of forming a lot of very small bubbles in the polyol. In order to accomplish the best possible effect, the argon needs to be distributed as finely as possible in the polyol, which is accomplished by adding argon slowly (maximally 1.5-2 liters/minute read on the flow meter). Moreover improved insulating properties are accomplished.

When the polyol is nucleared with gas/air the polyol contains thousands of very small bubbles. These bubbles are compressed to nearly nothing when the polyol is advanced while under high pressure, 100-220 bar, to the nozzle in the mixer head 13. From here return conduits extend to the tank 1. The return conduit is closed during firing. When the polyol travels through the nozzle, a dramatic pressure drop occurs that more or less triggers an explosion of the gas bobbles. This causes the polyol to be finely divided and also that the turbulence in the mixer chamber is increased, both of which greatly enhance the mixer effect.

Moreover each bubble is the seed of a cell. Since there are a number of bubbles for the polyol in excess of the number cells normally present in the finished foam, more cells will be formed which necessarily means smaller cells.

The thus formed polyurethane foam is conveyed downwards onto a metal plate intended therefor, and where it is subsequently closed by means of a further metal plate arranged on top of it. The manufacture of such panel often takes place in accordance with fully known principles as such.

Pentan is used as blowing agent and is admixed with the polyol.

Thus, in the above-recited example argon was used as additive gas in order to enhance the nucleus formation, while pentan is used as blowing agent. In tables 1 and 2 examples of other blowing agents and other additive gases are given.

Thus, Figure 2 shows a container 101 constructed from a number of panels 103. The container has an inner cavity in which cargo is arranged. During transport, the cargo 102 needs to maintain a given temperature by means of

a cooling device, the accomplishment of which is ensured by the heat-insulating panels 103.

Figure 3 thus shows a sectional view of a panel 103 constructed from two plane metal plates, an outer metal plate/outer metal coating 104 and an inner metal plate/inner metal coating 105. The inner metal plate 105 is typically manufactured from aluminium, while the outer metal plate is typically manufactured from a steel material. The metal plates have a minimum thickness of 50 μm to ensure that the plates are diffusion proof; in other words the gases, preferably pentan with argon, used in the manufacture of the polyurethane foam remain in the closed cells.

Besides, the plates are plane and arranged parallel in relation to each other with a distance of a minimum of 35 mm.

The outer metal plate 104 thus has an inner face 109 that faces towards the cavity provided by the two plate structures, while the inner metal plate 105 also has an inner face 110 facing towards the same cavity. This cavity is filled with preferably a polyurethane foam, and wherein the polyurethane foam fills the cavity 100% and has abutment on the full expanse of the inner faces.

Figures 4A and 4B show a foam material 106 in which a number of cells 107 are provided. The average diameter of the cells is desired to be preferably less than 0.4 mm, and further less than 0.25 mm. Figure 4A shows small cells while Figure 4B shows large cells that are indeed closed, but wherein the problem is precisely that, other things being equal, the heat rays penetrate fewer cell walls when the cells are large compared to the one shown in Figure 4A, where there are many cell walls, and therefore there will also be a lower heat radiation Q in case of the large number of small cells. Likewise it is of essence that the cells are closed; in other words that they are

on all sides cast integrally in the foam, the foam material used preferably being polyurethane foam. The gas in the cells 107 is preferably cyclopentan and CO_2 and argon, optionally admixed with other materials.

Table 1

Additive gas	mW/m°K
Atmospheric air	26.2
Carbondioxide	16.9
Helium	155.9
Neon	49.5
Argon	17.7
Crypton	9.5
Xenon	5.5

Table 2

Blowing agent	mW/m°K
HFC-365mfc	10.6
HFC-245fa	12.2
Cyclopentan	12.0
n-pentan	15.0
HFC 134a	14.9
Iso-pentan	13.8
CH_3CCl_2F, HCFC 141 b	9.4

Table 1 shows the thermal conductivity of various additive gasses, and it will appear that atmospheric air has a thermal conductivity of about 26.2 mW/m°K, whereas argon has a value of 17.7. Other gases that are also suitable, having low thermal conductivity, are eg crypton and xenon.

However, gases such as helium will have a far too high thermal conductivity, so will neon.

Examples of suitable blowing agents will appear from Table 2 with their associated values for thermal conductivity.

The correlation between the weight ratio and percent by volume for the preferred gases area as follows:

Percent by volume				
Weight ratio	1:50	1:50	1:400	1:400
Argon	3 %	-	0.40 %	-
Crypton	-	1 %	-	0.20 %
CO_2	36 %	37 %	36.90 %	37.00 %
Cyclopentan	61 %	62 %	62.70 %	62.80 %
	100 %	100 %	100.00 %	100.00 %

The blowing agent used is, as mentioned, preferably cyclopentan with argon as additive gas, where it may very well be admixed with other gases. The amount of closed cells should be within the order of a minimum of 90 % in order to achieve optimal insulation. In other words, the number of open cells may be up to 10 %. Likewise, it is essential that the gas used has a low coefficient of diffusion in the used foam material, which is thus preferably polyurethane, in those cases where the plates are manufactured from plastics material/plastics.

Now follows a description of a foam material according to the invention.

A rigid polyurethane foam was made using the following composition:

Polyol blend composition:	**Part by weight [g]**

Polyol made from sucrose and propylene oxide, OHV=450 mg KOH/g	71.6
Polyethylene glycol, OHV=290 mg KOH/g	10.0
Polypropylene glycol, OHV=112 mg KOH/g	5.0
Polyol made from glycerol and propylene oxide, OHV=250 mg KOH/g	9.0
Amine mixture	0.9
Water	2.0
Stabilizer mixture	1.5
Cyclopentane	13.0
Total	**113.0**
Polymeric MDI (DESMODUR 44V20) Total	**145.0**

The polyol blend was mixed with the polymeric MDI on a high pressure mixing head at 900 [g/sec]/160 [bar]/23 [°C] and introduced with a theoretical density of 48 [g/l] into a mould measuring 1500x860x70 [mm] held at 40 [°C] and kept there for 20 [min]. The argon was introduced into the polyol blend on the high pressure machine pipeline by an emulsifier at 5 [bar]/15 [NL/min]/8,000 [RPM] and the use of argon was controlled by a +/-1 [g] scale. Then the thermal conductivity of the polyurethane foam thus produced was tested after 24 [h] of conditioning on a Lasercomp according to ISO 8301.

Results:

	REFERENCE	1	2	3	4	Unit
Polyolblend	98.00	98.00	98.00	98.00	98.00	[g]
Water	2.00	2.00	2.00	2.00	2.00	[g]
Cyclopentane	13.00	13.00	13.00	13.00	13.00	[g]
Argon	-	0.06	0.09	0.15	0.22	[g]
P-MDI	145.00	145.00	145.00	145.00	145.00	[g]
			Weight percent of cell gas			
CO_2	27.1	27.2	27.2	27.1	27.0	[w/w%]
Cyclopentane	72.9	72.4	72.3	72.1	71.8	[w/w%]
Argon	-	0.4	0.5	0.8	1.2	[w/w%]
			Volume percent of cell gas			
CO_2	37.4	37.2	37.2	37.0	36.8	[vol%]
Cyclopentane	62.6	62.2	62.0	61.8	61.4	[vol%]
Argon	-	0.6	0.8	1.2	1.8	[vol%]

Thermal conductivity (+10 [°C] average temperature)						
Lambda value	20.4	19.8	20.2	20.4	20.5	[mW/mK]

As an alternative to argon, atmospheric air has been introduced into the polyol blend with the amount being approx. 1 [vol%] under same conditions as argon. The thermal conductivity of the foam was tested after 24 [h] of conditioning on a Lasercomp according to ISO 8301. The lambda value was found to be 21.6 [mW/mK].

Below is another test made with pentan-blown foam, to which argon was added:

Tests with pentan-blown foam with argon added

In laboratory test panels were made to investigate the effect of added argon on the insulating properties. Measurements based on laboratory tests show the correlation between the average wall temperature of 8.3°C and the insulating properties for the various relevant foam systems. See Figure 5.

The thermal conductivity is the lambda value for HCFC141b-, HFC 365/227, water-, pentan- and pentan/argon-blown polyurethane foam with a density of 42-44 (g/l).

It will appear that the pentan/argon system has increased insulating capacity at mean wall temperatures below 10°C, but increased at mean wall temperatures above same.

It should be noted that the graphs shown in Figure 5 are coded in accordance with the following:

I: 141b; II: pentan/argon; III: pentan; IV: 365/227; V: water.

The values along the X-axis are °C, while the values along the Y-axis are mW/m°K.

As mentioned, other gases can be used; for instance, carbon dioxide is also used along with cyclopentan and argon or crypton on one of the remaninig, mentioned gases, and wherein the essential aspect is thus that an amount is used of a gas having low thermal conductivity; that the cells in the polyurethane foam are small and are closed cells; and that the properties with regard to thermal conductivity are low. Moreover, it may be expedient if the selected gas is an inert gas, thereby reducing the risk of fire during the manufacture of the foam material.

The foam material used is primarily rigid or semi-rigid foam.

The described thermally insulated container can be used as it is and be charged with miscellaneous cargoes, for which it is desired to maintain a given and optimal temperature during transport. The mode of transport may be a loading of said containers onto vessels or railway vehicles.

The containers can also be incorporated in lorries in such a manner that the containers are integrated, whereby a refrigerated lorry is obtained for the transport of cargo on the highways.